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BUREAU OF CHEMISTRY—BULLETIN No. 160.

R. E. DOOLITTLE, Acting Chief of Bureau.

A STUDY OF NUTS WITH SPECIAL REFERENCE TO MICROSCOPIC IDENTIFICATION.

BY

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WASHINGTON:
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1912.

LETTER OF TRANSMITTAL.

U. S. Department of Agriculture,
Bureau of Chemistry,
Washington, D. C., May 31, 1912.

Sir: I have the honor to transmit for your approval a manuscript prepared in this bureau by Mr. W. J. Young, of the Microchemical Laboratory, on the microchemical examination of nuts with special reference to their identification when in a comminuted condition. This work is not claimed to represent an exhaustive study of the histology of the seeds, but is rather a study of those features which can be considered in the identification of the nuts when pure or mixed with others. Since there has been a demand for such information in connection with the examination of certain food products, I recommend that these results of investigations extending over several years be published as Bulletin 160 of the Bureau of Chemistry.

Respectfully,

R. E. Doolittle,
Acting Chief of Bureau.

Hon. James Wilson,
Secretary of Agriculture.

Additional copies of this publication may be procured from the Superintendent of Documents, Government Printing Office, Washington, D. C. at 10 cents per copy

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A STUDY OF NUTS WITH SPECIAL REFERENCE TO MICROSCOPIC IDENTIFICATION.

INTRODUCTION.

In connection with the miscroscopical examination of a number of nut products, which have from time to time been brought to the attention of the Bureau of Chemistry, the writer has had occasion to consult the literature of the subject, with the result that little or no reference could be found dealing in a satisfactory way with the microscopical structure of a number of important species of nuts. In this article an attempt has been made to supply the lack of readily accessible information, and hence certain nuts have been omitted, as the chestnut, acorn, beechnut, peanut, and coconut, good accounts of which are available,[1] as well as some of the rarer nuts which are not often encountered in the American trade.

Although intended primarily as an account of the minute structure of the nuts examined, occasionally notes of interest or value to the food chemist and others have been added. As a rule, the description of the pericarp was not attempted since this phase of the subject has been well investigated by others.

Most of the material used for the investigation was purchased on the market or contributed by members of the force of the Microchemical Laboratory. Samples of the California black walnut, the pecan, and several varieties of California-grown Persian walnuts were obtained from the growers by R. A. Gould, chief of the San Francisco Laboratory; authentic samples of the two forms of California black walnut were furnished by Ralph E. Smith, superintendent of the Southern California Pathological Laboratory; samples of canarium and cashew nuts were provided by C. F. Langworthy, expert in nutrition investigations, Office of Experiment Stations, while Japanese walnuts and apricot pits were obtained from W. A. Taylor, pomologist, Bureau of Plant Industry. The photomicrographs were made by B. J. Howard, chief of the Microchemical Laboratory, aided by the writer.

[1] Winton, Microscopy of Vegetable Foods, 1906, pp. 266–281; Hanausek, Microscopy of Technical Products, tr. by Winton and Barber, 1907, p. 387.

METHODS OF EXAMINATION.

Opaque structures, as preparations of integument, were cleared by boiling on a slide in a strong solution of chloral hydrate and were then mounted for examination in 50 per cent glycerin.[1] Sections were treated in the same manner after leaching out the oil with ether as they lay on a piece of filter paper. Preparations of aleurone grains were made by scraping the tissue lightly and mounting the scrapings in oil. Various oils were tried, as olive oil, xylol, etc., cedar oil being finally chosen as giving most satisfactory results.

In examining nut products the methods here outlined often have to be modified according to the nature of the preparation. In the case of almond paste it is usually possible to pick out from thin slices fragments of the integument, which may be washed in water and cleared for examination in chloral hydrate. It is necessary, however, to look over a rather large amount of the paste in order to find a sufficient number of fragments for an accurate determination of the source of the product. In examining a candy it is necessary first to get rid of the sugar, which is easily done by dissolving in hot water. The residue is then cleared for examination at once or after treatment with alcohol and ether for the removal of oil. Products containing large amounts of starch or flour, as cakes, pastry, etc., should first be examined for large fragments of nuts by cutting or breaking into small pieces. The residue is then crumbled finely and the official crude fiber method, as given in Bureau of Chemistry Bulletin 107, Revised, page 56, is applied to get rid of the starchy material and bring the residue into a satisfactory condition for microscopic examination. Since less accuracy is required in preparing the fiber for this purpose than in quantitative chemical work, the method may be somewhat simplified by boiling for a half hour in a 1 to 2 per cent solution of sulphuric acid, filtering, and boiling again for a half hour in a sodium hydroxid solution of about the same strength as the acid. After filtering, the crude fiber thus obtained is ready for examination in water or glycerin without further clearing.

ALMOND.

(*Amygdalus communis* L.)

GENERAL CHARACTERISTICS.

The bitter almond and the hard-shelled and soft or paper-shelled varieties of the sweet almond all belong to one species and are hence very similar in structure. There is a series of intermediate forms,

[1] A very satisfactory clearing and mounting agent for temporary slides is made by dissolving eight parts of chloral hydrate crystals in five parts of water and adding about 5 or 10 per cent of glycerin. The glycerin prevents to a great extent the formation of crystals even when the solution is boiled nearly to dryness. Mounts made in this way may be kept for some time, but for permanent preparations it is better to mount the cleared material in glycerin and seal with cover-glass cement or dehydrate and mount in Canada balsam.

some almonds being cracked as easily as a peanut, others having firmer shells, readily cracked by hand, and still others which can be cracked by hand with difficulty, if at all.

The form of the kernel is also subject to variation. The typical soft-shelled almond has a somewhat elongated elliptical and flattened kernel covered with a comparatively smooth, rather light-colored integument. The hard-shelled almond has a shorter, thicker, and more nearly oval kernel, with a rougher and darker integument (see fig. 1, A). Intermediate forms are common, especially in those strains having shells of intermediate thickness.

The hard-shelled almonds differ in flavor as well as in thickness and density of the shell. Some have no suggestion of bitterness; others are slightly bitter, but are not at all unpleasant. The typical bitter almond has so strong a flavor as to be inedible and in large amounts poisonous because of the presence of the prussic acid form-

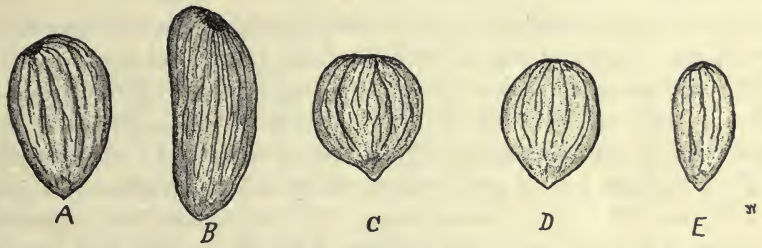


FIG. 1.—Kernels (natural size) of (A) hard-shelled almond, (B) Jordan almond, (C) apricot, (D) peach, (E) prune.

ing glucosid amygdalin. It is used for flavoring and in the manufacture of oil.

The Jordan almond, a hard-shelled variety, differs from the common varieties in form and has a thinner integument and a more delicate flavor. In consequence it brings a high price in market. The kernel is thicker and more elongated than that of the soft-shelled almond and is usually somewhat curved (see fig. 1, B). The supply is at present imported almost exclusively from southeastern Spain, where it is grown extensively, especially in the vicinity of Malaga. It has recently been introduced into this country and its cultivation undertaken in California. The origin of the name Jordan as applied to this variety is in doubt, some claiming that the first importations were reported to have come from the vicinity of the River Jordan, others contending that it is simply a corruption of the French word "jardin," garden.[1]

The almond tree has been found to grow in many parts of the United States, but its early blooming habits render it especially liable

[1] Fairchild. Spanish Almonds and their Introduction into America. U. S. Dept. Agr., Bureau of Plant Industry Bul. 26, p. 10.

to injury from late frosts, so that except in favored localities the crop is rarely a success. It is grown commercially in parts of California and the culture will probably extend eventually to a few other States as favored localities are discovered and varieties are originated which are less exacting in the climatic conditions to which they seem suited.

COMPOSITION AND USES.

The proportion of kernels to shells of almonds varies between wide limits, depending upon the thickness and density of the shell and the plumpness of the kernel. Two samples of soft-shelled almonds examined by the writer contained 61.2 and 63 per cent of kernels, respectively, while a sample of hard-shelled almonds contained but 36.1 per cent of kernels. These are fairly representative of the results obtained by other investigators, but of course do not represent extreme cases.

The chemical composition of the almond kernel, as well as that of most of the other nuts here considered, has been investigated by a number of chemists and analyses are given in most of the standard works on the composition of food products. The bitter almond differs slightly in composition from the sweet almond and contains in addition from 1 to 3 per cent of the glucosid amygdalin[1] and a small amount of the ferment emulsin. The latter has the property in the presence of moisture of decomposing the amygdalin and producing, among other products, hydrocyanic acid and benzaldehyde. These are the important constituents of the essential oil of bitter almonds and should be present in the proportion of from 2 to 4 per cent of hydrocyanic acid and not less than 85 per cent of benzaldehyde.[2] As a matter of fact, most of the commercial oil is below standard as regards the benzaldehyde, owing to the tendency of the latter to oxidize, forming benzoic acid.

Almonds are imported with the shells removed, as a rule, since the tariff renders the importation of shelled almonds more profitable than that of almonds in the shell. American-grown almonds, especially the soft-shelled varieties, are usually marketed in the shells, in which case they are sometimes whitened by bleaching. Blanched almonds are prepared by treating the shelled almonds with boiling water, rubbing off the skins, and thoroughly drying them. Almonds are also roasted and salted and sold as burnt and salted almonds. The kernels, either whole or chopped, are used in confectionery, cakes, and similar foods. Almond paste and almond meal are used in making macaroons and biscuits. A fixed oil is obtained from the kernels by pressure, and in the case of bitter almonds the residue is

[1] National Dispensatory, 1905, p. 163.
[2] U. S. Pharmacopœia, 8th rev., 1907, p. 306.

distilled, yielding the true essential oil of bitter almonds. The cake obtained in the manufacture of oil is a valuable stock food. The shells are employed as fuel or are sometimes finely ground and used to adulterate spices, a practice which can not be too strongly condemned. Even the hulls need not be wasted, as horses readily learn to eat them and they are a fattening food, as shown by analyses by Forbes and Skinner.[1] The presence of 7.34 per cent of tannin, however, is evidence that some caution should be exercised in using almond hulls as food for domestic animals.

HISTOLOGY.

The integument or spermoderm of the almond and related seeds consists of an outside layer of rather large cells, a middle layer of partially collapsed parenchyma cells through the outer portion of which the vascular bundles are distributed, and a delicate inside epithelium usually seen with difficulty. Of these the outside layer is, as a rule, sufficiently distinctive to enable one to determine the species to which the seed in question belongs. Wittmack and Buckwald,[2] however, do not consider the differences sufficiently characteristic to serve as a means of identification, while Godfrin,[3] on the other hand, states that the peach kernel is easily distinguished from the almond by the structure of the seed coat.

In the soft-shelled almond the epidermal layer consists of cells often 200 μ.[4] in diameter and seldom less than 100 μ. It is worthy of note in this connection that Hannig[5] found the diameter of the epidermal cells of the almond to vary from 23 to 124 μ, and a similar disagreement with the figures given here occurs in his measurements of the epidermal cells of the peach, apricot, and prune kernels. These epidermal cells are usually crowded closely together, but small intercellular spaces, in some specimens reaching considerable size, are occasionally found. The pale yellow cell walls are moderately thin and smooth, penetrated by pores only over the areas of contact between adjacent cells. Usually a few have thicker walls than others, suggesting the stone cells found in the epidermis of the hard-shelled almond, and this is especially noticeable in those strains of soft-shelled almonds having rather thick, firm shells.

The spongy parenchyma cells of the middle layer of spermoderm resemble in form those of the epidermal layer, but have thinner, mostly colorless, walls and seldom reach a diameter of 100 μ. In a

[1] Forage Products. Arizona Agr. Exper. Sta. Rept., 1902, pp. 268–270.

[2] Die Unterscheidung der Mandeln von ähnlichen Samen, Ber. d. Deuts. Bot. Ges., 1901, **19**: 591.

[3] Les Teguments Seminaux des Angiosperms. Bul. Soc. Sci. Nancy, 1880, p. 147.

[4] The micromillimeter or micron, commonly represented by the Greek letter μ (mu), equals 1/1000 millimeter, or about 1/25000 inch.

[5] Zts. Nahr. Genussm, 1911, **21**: 580.

transverse section these cells have a collapsed appearance. In some nuts rosette crystals, presumably of calcium oxalate, are found in cells of the tissue near the vascular bundles.

The endodermis consists of polygonal cells averaging about 35 μ in diameter but occasionally reaching an extreme length of 75 μ. The cell wall is irregularly marked by beadlike thickenings.

Closely adhering to the seed coat is a striated hyaline layer about 25 μ in thickness, which is probably to be regarded as perisperm or the remains of the nucellar tissue of the ovule. This lies next to a single layer of aleurone cells, about 25 μ or a little more in thickness, constituting the endosperm. A few cells may be found divided by walls parallel to the surface of the kernel. In surface view the endosperm is seen to consist of oblong or isodiametric quadrilateral or polygonal cells, the form apparently varying to a certain extent with the part of the kernel from which the tissue is taken. The cells vary up to 75 μ in length by 35 μ in width.

The epidermis of the cotyledons consists of elongated cells, as in the hard-shelled varieties described farther on, forming a layer not more than 10 μ in thickness. The parenchyma cells which make up the cotyledon tissue vary from the hypodermal cells with a diameter about twice as great as the epidermal cells to cells 40 to 50 μ in diameter, which make up the central tissue. The walls are thin and intercellular spaces very small. The cells contain oil and aleurone grains, which usually have a roundish or oval form, but occasionally are somewhat angular. Those measured varied in size up to 20 μ in length.

In the hard-shelled almond the epidermis of the integument consists of thin-walled cells as in the soft-shelled variety, with a large number of stone cells suggesting those of the pericarp, but having thinner walls (Pl. I, fig. 2). Their appearance has led some authors to the erroneous opinion that they represent cells of the pericarp clinging to the kernel.[1] Wittmack and Buckwald, however, consider these stone cells to be mere fragments of an original complete layer of similar cells, a large part of which has fallen away in the ripened seed.[2] Godfrin reports a complete layer of cells and recognizes two classes, ovoidal, and less conspicuous, flattened cells. He falls into the error, however, of considering the walls of the two classes of cells to be equally thickened.[3]

The inner and lateral walls of the stone cells are marked by pores which may be large or small, few or many, round or much elongated, all these variations being sometimes found in a single nut. These cells resemble in size the corresponding cells of the soft-shelled almond.

[1] Wittmack, L., and Buckwald, J., loc. cit., p. 589.
[2] Ibid., p. 587.
[3] Godfrin, loc. cit., pp. 146–147.

The outer wall, usually smooth and somewhat thicker than the inner and lateral walls, is sometimes flattened, but often protrudes as rounded papillæ. It is usually free from pores, though pores were noted in a few instances. The papillæ have been regarded by some investigators as representing hairs,[1] an opinion confirmed by their appearance in many cases. They vary considerably in height, some having been found near vascular bundles projecting 400 μ above the surface of the seed coat (Pl. I, fig. 1).

The parenchyma layer of the spermoderm is lacking in distinctive character, and the cell outlines are very indistinct. Its color is yellow or brownish. As in the soft-shelled almond, rosette crystals are present in some nuts and absent in others, but are more numerous than in that variety. The endodermis closely resembles that of the soft-shelled almond, but the cell walls are even more delicate and difficult to see.

The hyaline layer constituting the perisperm is about 5 μ thick and is adjacent to the aleurone layer, which varies up to 35 μ thick, consisting usually of a single layer of cells. In surface view these cells are indistinguishable from those of the soft-shelled almond, and, as in that variety, they vary considerably in size. When the tissue is treated with alkali or chloral hydrate the walls become swollen and somewhat indistinct, and the central lamina comes into view. (Pl. I, fig. 3.)

The epidermis of the cotyledons consists of oblong parallel cells averaging about 35 by 8 μ. (Pl. I, fig. 4.) The tissues of the cotyledons can not be distinguished from those of the soft-shelled almond.

The bitter almond is practically identical in structure with the hard-shelled sweet almond described above.

ADULTERANTS AND SUBSTITUTES.

In localities where peaches and apricots are grown extensively for drying, as in sections of California, the disposal of the pits presents a problem of interest to both the fruit grower and the consumer of almond products. The experiment of removing the pits from prunes previous to drying has recently been made, and should this process prove a financial success prune pits will eventually take their place beside those of the peach and apricot. This class of by-products was formerly used only for fuel, but more recently there has been an increased demand, especially for apricot pits, and investigation reveals the fact that in certain cases the kernels are substituted for bitter almonds. They are even exported to Europe, where the essential oil is distilled and mixed with or substituted for the oil

[1] Wittmack and Buckwald, loc. cit., p. 590.

of bitter almonds. Although the oil obtained from the seeds is practically the same in composition and properties as that distilled from bitter almonds,[1] and its use is allowed by the United States Pharmacopœia,[2] the wisdom of labeling such products strictly according to their origin can not be urged too strongly upon manufacturers and dealers. The apricot, peach, and prune seeds resemble those of the almond in structure, but differ from them in certain characteristic details, so that adulteration or substitution may readily be detected.

APRICOT KERNEL.

(*Prunus armeniaca* L.)

Apricot kernels (fig. 1, C), usually thinner than the almond but thicker than the peach kernel, are nearly circular or slightly oval in outline, with a small but distinct point marking the location of the radicle. They have nearly the odor and flavor of bitter almonds, but the bitterness is less intense. Apricot pits are better adapted than those of the peach as a substitute for bitter almonds, since the shells are thinner and the kernels larger and thicker, amounting to from 20 to 25 per cent of the weight of the entire pit.[3]

Histology.—The epidermal cells of the integument are from 50 to 100 μ in diameter, averaging about 75 μ or a little less. They have thin, slightly beaded walls. The epidermal stone cells are scattered over the surface with remarkable evenness, usually singly but sometimes two or three in contact. (Pl. II, fig. 3.) This evenness of distribution is not affected by the vascular bundles, as is so noticeable in the case of the peach, although the stone cells average somewhat smaller over the vascular region than over the surface generally. They are polygonal, or roundish, in outline, slightly hollowed where adjacent to intercellular spaces. The inner and lateral walls are marked with numerous round pores, a few of which are found also in the much thickened outer wall. The latter never appear to protrude sufficiently to suggest trichomes; they vary in diameter from 25 to 125 μ, averaging usually about 75 μ, and their height is seldom greater than their horizontal diameter. Hannig[4] has called attention to a characteristic appearance of the vascular bundles in the seed coat of the apricot. These bundles usually present the appearance of two parallel lines of vascular tissue with a clear space between, and give off many branches, usually at a large angle with the main bundles. The remaining tissues of the seed coat contain no characteristic elements and the parenchyma layer is without rosette crystals. The

[1] Rabak. Peach, Apricot, and Prune Kernels as By-products of the Fruit Industry in the United States. U. S. Dept. Agr., Bureau of Plant Industry Bul. 133, p. 25.

[2] U. S. Pharmacopœia, 8th rev., 1907, p. 306.

[3] Rabak. Loc. cit., p. 28.

[4] Zts. Nahr. Genussm., 1911, 21: 585.

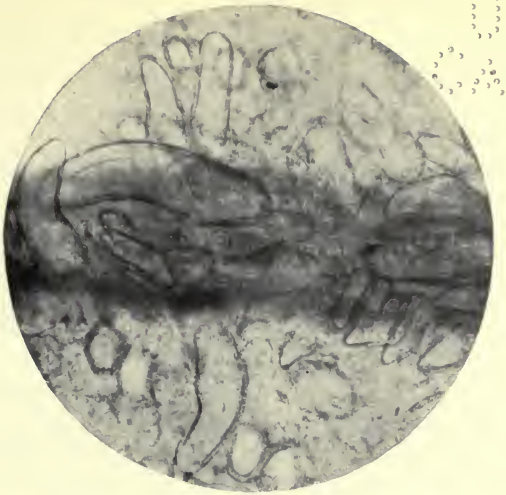


FIG. 1.—HARD-SHELLED ALMOND. HAIR-LIKE CELLS OF INTEGUMENT (× 75).

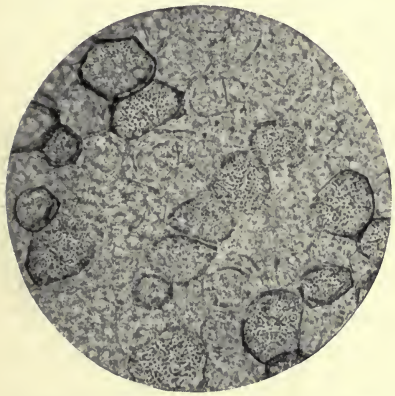


FIG. 2.—HARD-SHELLED ALMOND. SURFACE OF INTEGUMENT (× 75).

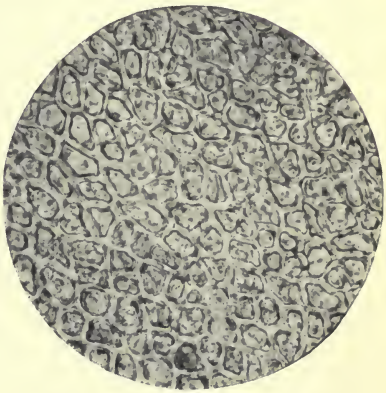


FIG. 3.—HARD-SHELLED ALMOND. ALEURONE LAYER (× 150).

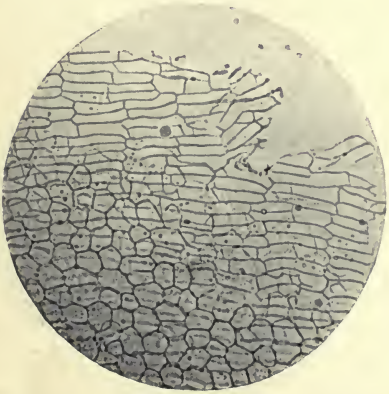


FIG. 4.—HARD-SHELLED ALMOND. EPIDERMIS OF COTYLEDON (× 175).

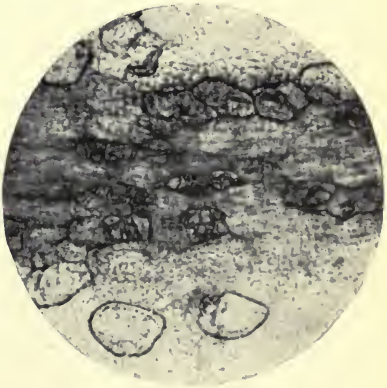


FIG. 5.—PEACH KERNEL. SURFACE OF INTEGUMENT (× 75)

FIG. 1—PRUNE. SECTION AT SURFACE OF KERNEL (× 175).

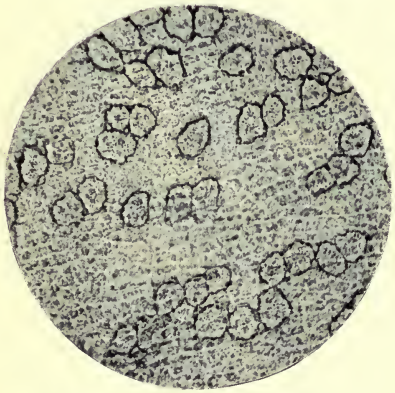


FIG. 2.—PRUNE. SURFACE OF INTEGUMENT (× 75).

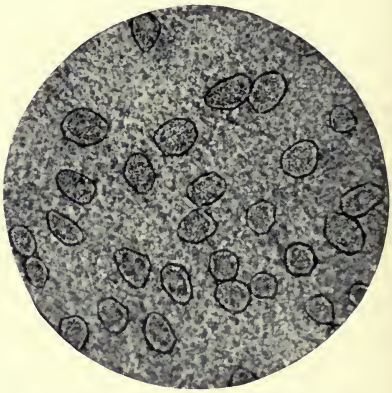


FIG. 3.—APRICOT. SURFACE OF INTEGUMENT (× 75).

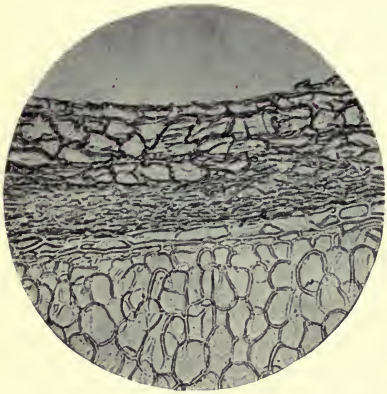


FIG 4.—FILBERT. SECTION AT SURFACE OF KERNEL (× 175).

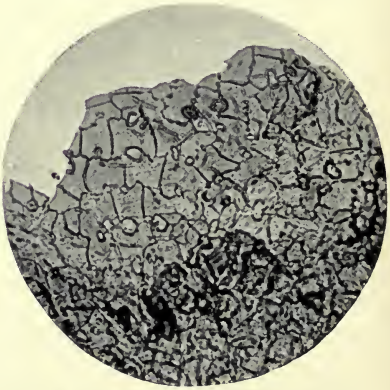


FIG. 5.—FILBERT. SURFACE OF INTEGUMENT (× 175).

aleurone cells are usually slightly smaller than those of the almond and the cell walls do not swell noticeably when treated with chloral hydrate.

In a transverse section the parenchyma layer is found to be thicker than in the almond, while the perisperm is comparatively thin. The endosperm consists of a single layer of cells about 20 μ in thickness. The cells of the embryo vary from 15 to 60 μ in diameter. The aleurone grains are roundish and granular looking, averaging 8 to 10 μ in diameter but sometimes reaching a diameter of 15 μ.

PEACH KERNEL.

(*Amygdalus persica* L.)

The peach kernel is more elongated than that of the apricot, being elliptical rather than circular in outline (fig. 1, D). It is also comparatively thin, with a rather sharp edge. It resembles the apricot kernel in flavor. According to Rabak the peach kernel comprises only from 6 to 12 per cent of the weight of the peach pit.[1]

Histology.—The epidermis of the integument resembles that of the almond more closely than does that of the apricot or prune. The numerous stone cells, arranged singly or in groups, are extremely variable in size, reaching a maximum diameter of 300 μ. According to Hannig[2] these cells form a continuous layer at the hilum, thus serving to distinguish the peach from the almond, in which these cells are scattered at the hilum as elsewhere. Groups of very small stone cells are common and highly characteristic of this species. They are especially numerous along the vascular bundles, where they often form long chains of cells quite different from anything found in the almond or apricot (Pl. I, fig. 5). These cells are sometimes 15 μ or less in diameter, although cells 50 μ in diameter are more common and may be considered about the average. Their height is but little greater than their diameter. As a rule the upper part of the stone cell is much narrower than the base and the outer wall is more thickened than in the almond.

The parenchyma layer is rather thin and often contains rosette crystals. The endodermis consists of brownish cells averaging 15 to 20 μ in diameter which are more easily seen as a rule than in any of the related species.

In cross section the endodermis appears as a lighter brown layer underneath the darker layer of parenchyma cells. The perisperm is quite noticeable, being in some places 12 to 15 μ thick. The endosperm consists of two distinct portions, the outer part, composed of four to six layers of aleurone cells, which is about 80 μ thick, becoming thinner near the edge of the kernel, and the inner portion

[1] Rabak. Loc. cit., p. 28. [2] Zts. Nahr. Genussm., 1911, 21: 584.

of which consists of a semihyaline layer of collapsed cells about 40 μ thick. The embryo has the same structure as the embryo in the almond. The aleurone grains are rather irregular in shape and of a granular appearance, varying in size up to 30 μ in diameter.

PRUNE KERNEL.

(*Prunus domestica* L.)

The kernel of the prune (fig. 1, E) bears a close resemblance in form to that of the almond but is considerably smaller, averaging in length scarcely more than one-half that of the latter. The hilum is conspicuous as a winglike fold of the integument extending for a short distance along the edge of the kernel at its base. The flavor though somewhat bitter is milder than that of the peach or apricot, owing no doubt to the smaller content of amygdalin. Although prune pits are considerably smaller than those of the apricot, a sample examined by the writer contained 21.2 per cent of kernel, an amount which compares favorably with the apricot.

Histology.—The seed coat of the prune resembles closely that of the apricot. (Pl. II, fig. 2.) The epidermal cells have thin walls and vary in length up to 200 μ, averaging from 100 to 125 μ. The stone cells vary from 40 to 150 μ in length, averaging about 100 μ. Pores are present as in the stone cells of the apricot, but are less numerous in the outer wall. The height of the cells is usually less than the diameter, and in side view they present a low domelike appearance, with a very thick outer wall. Although arranged in much the same manner as in the apricot, they display a greater tendency to grouping and especially to arrangement in rows. Intercellular spaces are numerous and of large size, so that their effect in hollowing the sides of the stone cells is very noticeable. As seen in cross section (Pl. II, fig. 1), the seed coat appears to be very thin, usually not over 50 μ in thickness, with a brownish outer layer, a lighter middle layer of collapsible looking cells, and a thin brown inner layer. These tissues contain no crystals. No perisperm is discernible, although the outer hyaline membrane of the endosperm may be derived from the perisperm. The endosperm varies in thickness within wide limits. Over the edges of the kernel it is but 25 μ thick and composed of one or two layers of cells. In this form it extends for a short distance over the sides of the kernel, where it begins to thicken rapidly, reaching a thickness of 350 μ or more over most of the lateral faces of the kernel. The inner endosperm cells have a collapsed appearance.

The epidermis of the cotyledons is about 10 to 15 μ thick. The cells are larger and more distinctly visible than those in the species already described, reaching an extreme length of 100 μ and a width

of 20 μ. The cotyledons resemble in structure those of the almond. The aleurone grains are somewhat irregular in shape and vary in diameter up to 20 μ.

WALNUT.

(*Juglans*, Family *Juglandaceæ*.)

CHARACTERISTICS AND USES.

The name "walnut" is of Anglo-Saxon origin, meaning "foreign nut," from the fact that the so-called English walnut was introduced into Great Britain at an early date from the southern part of Europe. Walnuts are readily distinguished from hickories by the fact that the outer pericarp does not split open regularly as the seed matures, but usually dries up on the nut, necessitating a husking process before the nut is put on the market.

Walnuts are marketed whole, or the meats are removed from the shells and sold for use in confections, cakes, etc. All the species are rich in oil, which is sometimes extracted by pressure, but is not much used except in certain parts of Europe. Green walnuts are pickled or used in making walnut catsup.

Finally, it is worthy of note that among the nuts those of the order Juglandaceæ are peculiar from the histological standpoint in the possession of stomata on the epidermis of the seed coat, and this is one of the most characteristic features used in distinguishing the species by means of the microscope.[1]

VARIETIES.

PERSIAN OR ENGLISH WALNUT.

(*Juglans regia* L.)

This nut was known to the ancient inhabitants of the Mediterranean region, who obtained it from its supposedly native country, Persia, and named it accordingly. In point of priority, therefore, the name Persian walnut should take precedence over the more popular name of English walnut. It has been grown for ages in the milder parts of Europe for the sake of its timber and nuts. Trees were planted in this country at an early date; but the climate of the northeastern States being unfavorable, it remained for the Pacific coast States to develop walnut growing on a commercial scale.

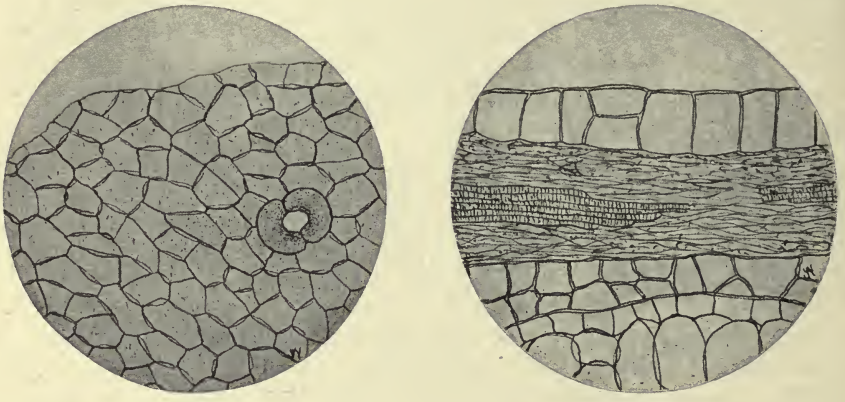
In this species the outer pericarp breaks more or less irregularly when the nuts mature and the nuts fall to the ground or can be easily shaken from the tree. The outer pericarp, or husk, may or may not fall with the nut, but in case it does it is usually split to

[1] Godfrin. Loc. cit., p. 138.

such an extent as to be easily removed by the pickers at the time of harvesting. In the walnut groves of California no special machinery is required to remove the outer pericarp, except where the nuts have been sunburned or for some other reason have failed to develop normally.

Walnuts are further prepared by bleaching with a solution of chlorid of lime, sodium carbonate, and a little sulphuric acid or other bleaching agents. Polishing with soapstone is also resorted to occasionally.

Walnut varieties differ in hardiness, size of nuts, and thickness of shell. The proportion of kernels varies, according to Colby, from 25.9 to 45 per cent.[1] Three fairly representative samples examined by the writer contained, respectively, 40.8, 41.1, and 47.6 per cent of kernels.



A B

FIG. 2.—Persian walnut: A—Epidermis of integument (×175); B—Section of integument and superficial tissues of kernel (×175).

Histology.—The kernel of the Persian walnut has a fairly thick integument which often separates easily from the meat. The outer portion is quite sharply differentiated from the inner cell layers. It consists of turgid cells varying in diameter up to 80 μ, but averaging about 30 to 40 μ, which present a foamlike appearance (fig. 2, A). Stomata occur at intervals in the epidermal layer. They are characterized by thick reniform guard cells, quite regular in shape, almost always fitting together squarely at the ends. Stomata measure about 55 μ in length by 70 μ in breadth. The opening included by the guard cells is also broader than it is long and usually has a symmetrical form. In a transverse section (see fig. 2, B) the outer tissue is seen to have a thickness of 60 to 80 μ and to consist in general of

[1] Colby. California Walnuts, Almonds, and Chestnuts. California Agr. Exper. Sta. Bul. 113, p. 4.

one or two cell layers. The stomata are subtended by rather small respiratory cavities. The inner periderm layer is 20 μ or more thick and consists of compressed cells forming a parenchyma tissue which lacks distinctive character and in some places contains large vascular bundles.

The endosperm comprises a rather thin layer, 16 to 40 μ thick, closely joined to the kernel. It usually consists of a single cell layer, which at intervals becomes thickened to two or three layers. The cells are usually much elongated. The epidermis of the cotyledons consists of cells smaller than those of the endosperm. In surface view they are angular and vary considerably in form, while the walls are thin and slightly beaded. This layer lies close to the parenchyma cells of the cotyledon, averaging about 50 to 60 μ in diameter. These cells are sometimes arranged in lines perpendicular to the surface of the kernel or of the convolutions in the interior of the cotyledon. The surface of these convolutions is covered with an epidermal layer similar to that of the exterior of the cotyledon, and the narrow inclosed space sometimes contains a layer of hyaline matter probably derived from the endosperm. In addition to oil, the embryo contains aleurone grains which are seldom more than 10 μ in diameter. Their structure is not characteristic.

BUTTERNUT OR WHITE WALNUT.

(*Juglans cinerea* L.)

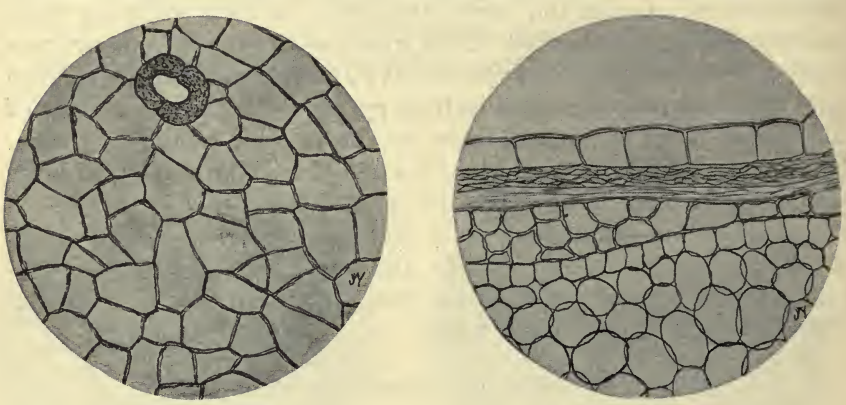
The butternut is a well-known native tree producing elongated pointed nuts having a thick shell and a very rough surface, to which the outer tissues of the pericarp cling tenaciously. The oily kernels are of high quality, but the nuts of most trees are of little commercial importance on account of the thick shell. It is not improbable, however, that the present search by nut growers for individual trees bearing nuts of thin shell and of high quality, from which to propagate, will result in the development of valuable varieties and an increased production of this nut. According to Lazenby [1] butternuts contain 21 per cent of kernels, while Woods and Merrill found only 13.6 per cent.[2] The latter is probably abnormally low, as the writer obtained 22.1 per cent.

Histology.—The outer cells of the seed coat are considerably more angular in appearance than those of the Persian walnut, and also, as a rule, decidedly larger (fig. 3, A). While their average diameter is about 50 μ, cells 100 μ in length are occasionally seen. Stomata are quite numerous and measure 40 to 60 μ in length and 70 to 80 μ

[1] Composition and Waste of Fruits and Nuts, Proc. Soc. Prom. Agr. Sci. 1903, p. 101.
[2] Nuts as Food, Maine Agr. Exper. Sta. Bul. 54, p. 81.

in breadth. The guard cells are horseshoe-shaped, not so thick as those of the Persian walnut. As a rule, the ends fit together squarely, so as to inclose an opening four or five times as broad as it is long. One guard cell often remains but slightly developed, and in some cases both guard cells appear shriveled. As seen in the section (fig. 3, B), the outer tissue consists in general of a single layer of cells 25 to 30 μ thick, while the inner tissue is not noticeably different from that of the Persian walnut, though sometimes only 15 μ thick.

The endosperm is from 40 to 60 μ thick and consists of from one to three layers of cells. It has a thick hyaline outer wall, which may



A B

FIG. 3.—Butternut: A—Epidermis of integument (×175); B—Section of integument and superficial tissues of kernel (×175).

possibly be regarded as the perisperm. The embryo has the same structure as in the last described species. The aleurone grains average 7 to 8 μ in diameter and seldom exceed 12 μ.

BLACK WALNUT.

(*Juglans nigra* L.)

Up to the present time the native black walnut has been of greater importance as a timber tree than as the source of a food product. The nuts, however, are placed upon the market each year, and while they have not as yet met with great demand, the uses to which they may be put are now on the increase, and the demand is proportionately greater. The shell of the black walnut is usually thick and the kernels are not always plump. The flavor is quite distinctive, being greatly relished by some and disliked by others.

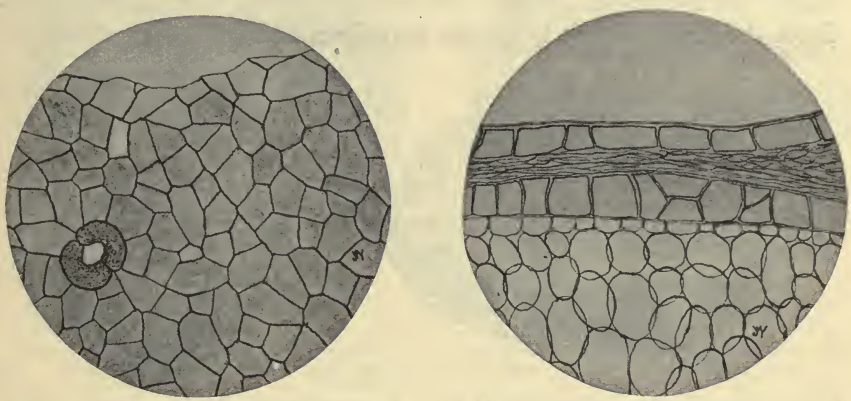
The black walnut is approximately spherical, slightly flattened at the sides and usually somewhat prolonged at the ends. The surface is roughened, but to a less extent than in the butternut. According to Lazenby,[1] the proportion of kernels varies with the size of the

[1] Composition and Waste of Fruits and Nuts. Proc. Soc. Prom. Agr. Sci., 1903, p. 101.

nuts from 18 to 20 per cent. The writer, however, obtained 21.3, 24.4, and 24.6 per cent from three average commercial samples.

Histology.—The epidermal cells of the seed coat, though resembling those of the Persian walnut, are more angular and have a clouded, opalescent, or smoky appearance, due apparently to the color of the cell contents (see fig. 4, A). The stomata are roundish or slightly broader than long, measuring about 45 to 50 μ by 50 to 60 μ. The guard cells are usually narrower than those of the Persian walnut and the butternut, and are about as numerous as those in the latter species. They are often more coiled than those in the other species thus far considered, suggesting somewhat the character so conspicuous in the two following species.

In the transverse section (fig. 4, B), the outer periderm tissue is seen to consist of a single layer of cells of very even thickness,



A B

FIG. 4.—Black walnut: A—Epidermis of integument showing opalescent character of cell contents (×175); B—Section of integument and superficial tissues of kernel (×175).

amounting to about 20 μ. The cells contain much tannin, the presence of which is readily demonstrated by treatment with ferric chlorid. The inner layer of periderm cells is like that of the butternut.

The endosperm consists of a single layer of cells, occasionally divided tangentially, and often containing irregular yellow masses. The cotyledon tissues are like those of the other walnuts described. The aleurone grains closely resemble those of the butternut.

JAPANESE WALNUT.

(*Juglans sieboldiana* Maxim., *J. cordiformis* Maxim., and *J. mandshurica* Maxim.)

Three types of walnuts, natives of Eastern Asia and Japan, were described by Maximowicz, who gave them the names mentioned above. The first is a fair-sized ovoidal nut, the second is smaller and decid-

edly heart-shaped, while the third is elongated, roughened, and very similar in size and appearance to the native *J. cinerea*. Whether these forms are to be ranked as distinct species is a question not entirely settled, as it is certain that they display a marked tendency to fail to come true from seed, and it is the common opinion that seedlings grown from nuts of any of the three types may produce nuts of the other types or of intermediate character. In vegetative characters, moreover, these three forms appear to be practically identical, this fact being explained in either of the following ways: (1) That they are three separate but ill-defined and variable species, distinct enough in their extreme forms, but connected by intermediate stages and overlapping in their variations, possibly as a result of intercrossing; (2) that there is but a single exceedingly unstable species, possibly in a state of mutation, the original form giving rise mainly to two types. Since the form known as *J. sieboldiana* produces the finest nuts, it is the one here described (fig. 5, A).

A B

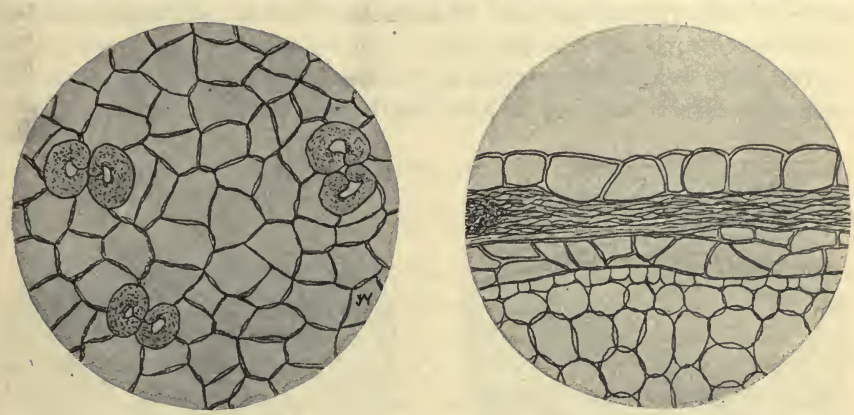
FIG. 5.—A—Japanese walnut (natural size); B—California black walnut (natural size).

The Japanese walnuts are usually smaller than are the nuts of either *J. regia* or *J. nigra*, while the surface features of the shell are intermediate between the two species. The shells are moderately thick, the kernels smooth, plump, of good quality, and relished by most people. The tree is hardy and productive, and although these nuts do not offer as great promise as do the native species, they should be included in home plantings wherever successful. A small sample examined by the writer contained 26.92 per cent of kernels.

Histology.—The outer layer of the periderm resembles closely that of the Persian walnut, but the cells are slightly more angular, and hence the foamlike appearance is less marked (fig. 6, A). The stomata, however, are peculiar. The guard cells are nearly always coiled into complete circles with the ends meeting or, in some cases, even overlapping. The length is, therefore, much less than the width, these dimensions being usually 40 to 50 μ and 60 to 80 μ, respectively. They are much more numerous than in the Persian walnut. In the

transverse section (fig. 6, B) the outer periderm tissue is found to consist of a single cell layer 30 to 40 μ in thickness. The inner layer is a thin, dark-colored tissue not unlike that of the Persian walnut.

The endosperm consists of two or three layers of cells, forming a tissue of quite uniform thickness, amounting to 30 to 40 μ. It adheres closely to the integument. The thick outer walls of the aleurone cells form a hyaline layer suggesting the remains of the perisperm. The epidermis of the cotyledons consists of small cells 12 to 16 μ in thickness. The parenchyma of the cotyledons is much like that of the Persian walnut, though less tendency to a linear arrangement of the cells was observed. The aleurone grains vary up to 16 μ in



A B

FIG. 6.—Japanese walnut: A—Epidermis of integument showing coiled guard cells (×175); B—Section of integument and superficial tissues of kernel (×175).

diameter, but probably do not average more than 10 μ, differing from those of the Persian walnut mainly in size.

CALIFORNIA BLACK WALNUT.

(*Juglans californica* Watson and *Juglans californica hindsii* Jepson.)

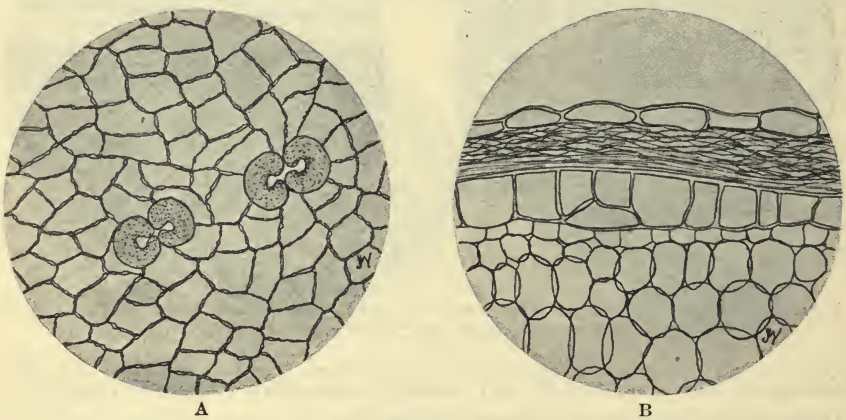
Since the native California walnut was shown by Watson to be distinct from *J. rupestris*, it has been the custom to apply the name *J. californica* to all of those nuts known as California black walnuts. Recently two distinct types of California walnuts have been recognized, and Jepson has given the name *J. hindsii* to the larger form, which is found in central and northern California, restricting the name *J. californica* to the more shrubby type with smaller nuts, which grows in the southern part of the State. *J. hindsii* is not, however, universally accepted as a distinct species. Its resemblance to the eastern black walnut, *J. nigra*, would lead to the suspicion that it is a hybrid between that species and *J. californica*, a supposition

which is strengthened by the fact that there are few places where the tree appears to be indigenous.[1]

In microscopic structure, however, it appears to be quite distinct from either. As it is the form more generally and widely distributed, it is the one here described in detail (fig. 5, B). It resembles in form the eastern black walnut, is smaller, as a rule, and is less pointed at the base, with a nearly smooth shell marked by occasional small protuberances, especially along the sutures. The kernel is rather small, and has a milder flavor than that of the eastern black walnut.

J. californica, only about half as large as *J. hindsii*, is very short in proportion to its thickness, and has a smoother shell. Woods and Merrill[2] report 25.9 per cent of kernels. The sample examined by the writer contained 27.5 per cent.

Histology.—The outer cells of the integument average 35 μ in diameter, rarely reaching 70 μ in length (fig. 7, A). They are angu-



A B

FIG. 7.—California black walnut: A—Epidermis of integument showing coiled guard cells (×175); B—Section of integument and superficial tissues of kernel (×175).

lar with somewhat wavy walls, and are, as a rule, slightly elongated. The cell contents have a slightly opalescent appearance, suggesting those of *J. nigra*, but much less noticeable than those in that species. Stomata are numerous and resemble those of the Japanese walnut already described. The guard cells, however, are broader than in that species, each one forming an almost perfect circle, so that the entire structure has a breadth nearly twice as great as its length. The usual dimensions of the stomata are 36 by 64 μ. It frequently happens that the opposite ends of the guard cells are not quite in contact, as a result of which a long, narrow transverse opening is produced. The outer periderm tissue consists of a single layer of cells 20 μ thick (fig. 7, B). The inner periderm is a layer of varying

[1] Smith, California Agr. Exper. Sta. Bul. 203, p. 27.
[2] Nuts as Food, Maine Agr. Exper. Sta. Bul. 54, p. 75.

thickness in which it is difficult to distinguish cell outlines. Thickened vascular areas occur at intervals.

The endosperm is a single layer of cells, some of which may be divided transversely, 40 to 50 μ thick and united closely with the embryo. The latter consists of roundish cells about 50 μ in diameter. The embryo is rich in aleurone grains, which average about 10 μ in diameter, occasionally reaching 15 μ.

In *J. californica* the epidermal cells of the integument are angular and more nearly isodiametric than in *J. hindsii*. They are also much smaller, having an average diameter of about 20 μ. Stomata are numerous; they are about 45 μ long and 52 μ broad, with very broad guard cells inclosing a relatively small and narrow opening. There is no suggestion of the coiling of the guard cells so noticeable in *J. hindsii*. The seed coat is about 35 μ thick, and the aleurone layer, which consists of about two cell layers, has a thickness of about 50 μ.

HICKORY NUT.

(*Hicoria*, Family *Juglandaceæ*.)

The most striking difference between the walnuts and the hickory nuts is in the character of the outer pericarp or husk, which, in the latter, splits at maturity into four valves of a dry, leathery texture, permitting the escape of the smooth, often more or less angular nuts. Of the dozen species native within the United States, with few exceptions all but three produce nuts of too poor quality or bitter taste to be useful as food. The shellbark, or king nut, *H. laciniosa* (*Michx. f.*) Sarg., is less common in the market than either of the other species, and as material for study was not readily available it is not considered in this paper.

PECAN.

(*Hicoria pecan* (Marsh.) Britt.)

From a commercial standpoint the pecan is by far the most important of native nuts. Its smooth shell, attractive appearance, abundant production, plump kernels, which are usually extracted with ease, and high quality are largely accountable for its popularity. The nuts are of various types, ranging from oblong cylindrical to almost spherical. Those used in these studies were elongated, somewhat pointed, of a grayish-brown color, and frequently splashed with dark-colored markings. The husk of the pecan varies greatly in thickness and does not always split entirely to the base until after the nut has matured and fallen normally. Seedling pecan trees present a wide variation in size and shape of nuts and thickness of shells. Propagation from the best of these seedlings has resulted in the production of

many improved varieties in recent years, as a result of which much interest has been aroused in pecan culture, especially in the eastern Gulf and South Atlantic States.

As a native of the forest the pecan does not cover as large an area as do many other species of forest trees. It is common in the bottom lands adjacent to the Mississippi and its tributaries from Davenport, Iowa, and Terre Haute, Ind., on the north over a rather broad area extending southwestward to the lower Rio Grande.[1]

It has been introduced to a very large extent into the States of Georgia, Florida, Alabama, the Carolinas, and to some extent in lower Virginia. Interest in pecan growing in the northern States is just now being aroused by the origin of several choice varieties in southern Indiana, northern Kentucky, and lower Virginia, which give considerable promise to the pecan future in sections of similar climatic, soil, and moisture conditions.

Pecans of the named varieties are as yet marketed in their natural condition, without stain or polish. A large portion of the native nuts are dipped in a reddish-colored dyeing solution, dried, and polished, after which they are placed upon the market. Nut-cracking establishments are located in the pecan sections and principal distributing points of the northern States, the product of which, graded as whole or broken half kernels, is sold in the markets of the country at large.

Lazenby[2] reports 38 to 49 per cent of kernels, according to the size of the nuts. It is the opinion of the writer, however, that the proportion of kernels is dependent more upon the thickness of the shells, which is an individual or varietal characteristic, than upon the size of the nuts. Four commercial samples examined gave 40, 40.2, 40.4, and 42.8 per cent of kernels. These samples represented nuts of different sizes, from small to large, in the order reported, but each contained both thick and thin shelled nuts, thus bringing the result somewhere near the average for the species. In the named varieties the proportion of kernel depends upon the variety and usually runs from 45 to 55 per cent, but occasionally reaches 62 or 63 per cent of the nut.

Histology.—The epidermal cells of the integument average about 75 μ in length and are usually from one-fourth to one-half as broad, much less commonly isodiametric (fig. 8, A); cells 120 μ or more in length are sometimes found. The walls are thin and appear to be slightly beaded. On account of the thickness of the outer layer of spermoderm it appears from the surface much like a mass of parenchyma. Stomata are fairly common. They are very nearly circular

[1] The Pecan and its Culture, U. S. Dept. Agr., Bureau of Plant Industry Bul. 251.
[2] Proc. Soc. Prom. Agr. Sci., 1903, p. 101.

and about 40 μ in diameter. The guard cells are narrow, resulting in a comparatively wide opening. One guard cell is sometimes smaller than the other or apparently abortive.

In the transverse section (fig. 8, B) the outer periderm tissue is found to consist of three or four layers of cells and to reach a thickness of about 40 μ. The thin layer of inner periderm tissue resembles that of the walnuts already described. The endosperm consists of a single layer of cells about 15 to 20 μ thick, while the epidermis of the

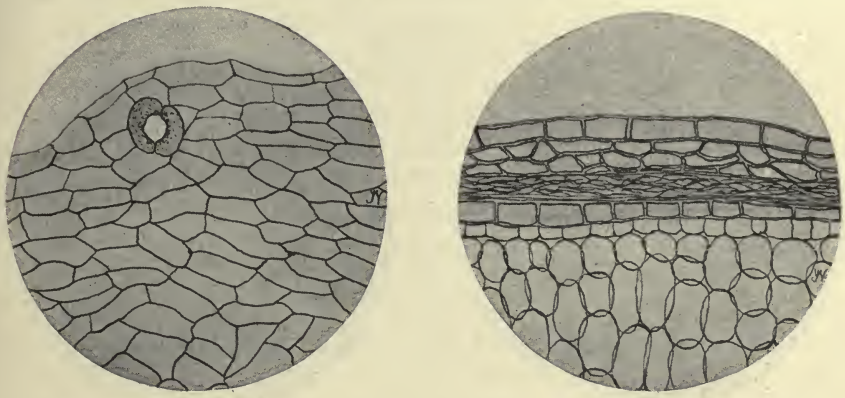


FIG. 8.—Pecan: A—Epidermis of integument showing elongated cells (×175); B—Section of integument and superficial tissues of kernel (×175).

cotyledons is about 10 μ thick. The parenchyma of the embryo resembles that of the Persian walnut. The aleurone grains reach a maximum diameter of about 10 μ with an average of 4 to 5 μ.

LITTLE SHAGBARK OR SHAGBARK HICKORY.

(*Hicoria ovata* (Mill.) Britt.)

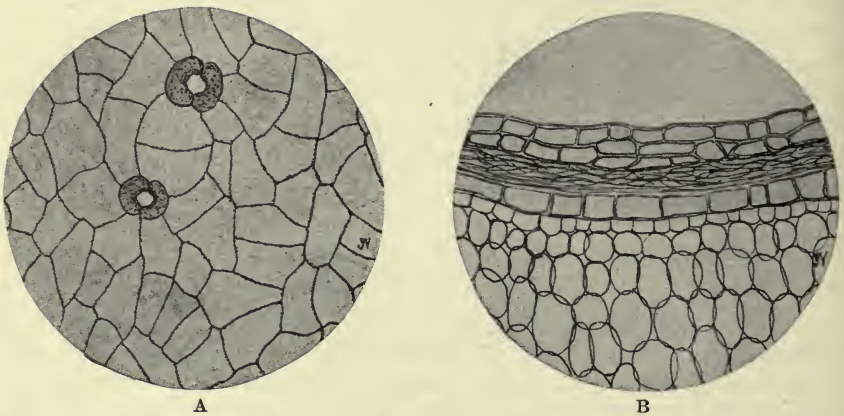
The common hickory is of wide distribution and the nuts are too well known to require description in this place. Unfortunately the shell is rather thick and the nut appears to be less variable than the pecan. As wild nuts are usually abundant little has been done along the line of searching for improved varieties worthy of cultivation. Woods and Merrill[1] report 37.8 per cent kernel, while Lazenby[2] gives 32 per cent. Nuts obtained by the writer from three different trees growing in the same locality in eastern New York gave 32.8, 35.4, and 37.1 per cent of kernels, respectively.

Histology.—The epidermal cells of the periderm average about 30 to 40 μ in diameter. They are more angular than those in most of

[1] Maine Agr. Exper. Sta. Bul. 54, p. 75. [2] Loc. cit., p. 101.

the walnuts, but not so elongated as those of the pecan (fig. 9, A). The walls are moderately thick and somewhat beaded. The stomata are nearly circular and about 30 μ in diameter. They are rather less numerous than in the pecan. The guard cells are comparatively broad and the opening fairly wide.

In the transverse section (fig. 9, B) the outer tissue is found to have a thickness of about 30 μ and to be composed of two or three layers of cells. The inner periderm layer is like that of the pecan. The endosperm is 25 to 30 μ thick and is composed of a single layer



A B

FIG. 9.—Hickory nut: A—Epidermis of integument showing nearly isodiametric cells (×175); B—Section of integument and superficial tissues of kernel (×175).

of cells, many of which are divided by horizontal walls. The embryo tissues resemble those of the pecan and contain aleurone grains slightly smaller than those in that species.

MISCELLANEOUS NUTS.

HAZELNUT, FILBERT, OR COBNUT.

(*Corylus avellana* L., and other species, Family *Betulaceæ*.)

Although the names "hazel" and "filbert" are not regarded as strictly synonymous, they are loosely used and there is no well-marked distinction between the nuts to which these terms are applied. The literal meaning of filbert is "full beard," and according to Fuller[1] this name should be applied to those varieties in which the husk is fringed and extends beyond the nuts, while varieties with a short husk should be termed "hazel." Others apply the name "filbert" to the cultivated nuts, reserving the term "hazel" for the wild forms. The cultivated varieties are mostly derived from the Eu-

[1] Nut Culturist, p. 118.

ropean species, *C. avellana* L. and *C. pontica* Koch. The American species, *C. americana* Walt. and *C. rostrata* Ait., have not produced cultivated varieties to a great extent and are of comparatively little importance commercially, although both are worthy of special attention on account of the failure of most attempts to introduce the European varieties in this country. These failures are due to the hazel blight, a disease caused by the fungus *Cryptospora anomola* Pk. This disease, although common on *C. americana*, is not especially injurious to that species, and doubtless could be prevented in the European varieties by proper spraying.

The proportion of kernels is given by Woods and Merrill[1] as 47.9 per cent, although the writer obtained but 37.5, 38.4, and 39.4 per cent from three average commercial samples.

Histology.—The kernel of the hazelnut is covered by a rather thick reddish-brown integument, to which usually adhere some of the cells of the spongy endocarp. The latter have thin, brown walls, usually much wrinkled and collapsed, which vary from 50 to 100 μ in diameter. The epidermis of the spermoderm consists of angular cells of variable shape with an average diameter in the variety examined of 25 to 30 μ and an extreme length of 72 μ (Pl. II, fig. 5). This is the most characteristic tissue of the nut on account of the intercellular openings, which pierce the cell layer and seem to take the place of stomata, which are absent. These spaces, occasionally located at the angles of the cells, but more frequently at intermediate points, are rounded or elliptical in shape, in the latter case with the long axis at right angles to the cell boundary. Though varying considerably in size, they are seldom more than 20 μ in diameter and are sometimes represented merely by thickenings of the cell walls. They are rarely absent.

Underneath the epidermis is a thin layer of spongy parenchyma, which in surface view closely resembles the epidermis. The intercellular spaces as well as the cells, however, are larger, and the latter have a more rounded outline. This layer is succeeded by a tissue formed of compressed cells of a light brown color, the outlines of which are seldom discernible.

The spermoderm is well supplied with vascular tissue in broad bands, which start at the chalaza and pass in curved lines over the top and sides of the nuts toward the hilum. Each band is composed of a large number of vessels of the spiral and annular types, about 10 to 15 μ in diameter.

The endosperm comprises a layer about 15 to 25 μ thick, made up usually of one or two cell layers. The epidermis of the cotyledons is not more than 10 μ thick and is composed of cells usually under

[1] Loc. cit., p. 73.

25 μ in diameter. The tissue of the cotyledons consists of parenchyma cells with thinner walls than those of the endosperm, varying in diameter from 20 μ in the outer part to 50 to 75 μ in the interior. Intercellular spaces, though present, are very small. These cells contain oil and spheroidal aleurone grains up to 20 μ in diameter, the structure of which has been described by Hanausek.[1] The arrangement and relations of the various tissues are shown in Plate II, figure 4.

PINE NUT OR PIÑON.

(*Pinus* sp., Family *Pinaceæ*.)

The large edible seeds of a number of species of pine are employed as food, both in this country and in Europe. The American Indians in particular formerly made great use of the seeds of *Pinus edulis* Engelm., *P. cembroides* Zucc., *P. Monophylla* Torr. and Frem., and others. In some parts of the West at the present day the Indians collect pine nuts in considerable quantities, both as food and for sale. The pines of Europe producing edible seeds are *P. cembra* L. and *P. pinea* L.

It is necessary to collect and roast the cones in order to cause the scales to spread apart, after which the seeds are easily dislodged. Pine nuts are prepared for market by cracking, after which the delicate, loose-fitting inner integument is easily rubbed off, only traces of it being found in the samples examined. These were of the kinds offered by dealers, and it was not possible to determine the species. The structure of the various kinds is, however, very similar.

The kernel is irregularly long-ovoidal in form, white, oily, and of a delicate, often slightly resinous aromatic flavor. The thick endosperm surrounds a cylindrical cavity containing the straight embryo, which consists of a rather large radicle bearing at its extremity a whirl of cotyledons inclosing the growing point of the embryo. Woods and Merrill [2] report about 60 per cent of kernels and a chemical composition varying considerably with the species.

Histology.—The pine nut is simple in structure and lacks characteristic features. The kernel is covered by a thin brown membrane composed of large cells commonly varying in the nuts examined from 400 to 600 μ in length and from 60 to 80 μ in breadth. (Pl. III, fig. 1.) The walls are thin and the cells as a rule have a more or less collapsed appearance.

The endosperm consists of thin-walled parenchyma cells varying in diameter in different parts, but averaging about 40 μ. The cells of the embryo are similar, but somewhat smaller. The reserve food

[1] Ref. by Winton in Microscopy of Vegetable Foods, 1906, p. 311.
[2] Loc. cit., p. 83.

FIG. 1.—PINE NUT. SURFACE OF INTEGUMENT (× 75).

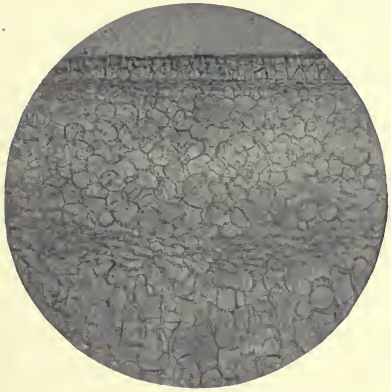


FIG 2.—BRAZIL NUT. SECTION AT SURFACE OF KERNEL, NOT INCLUDING THE INTEGUMENT (× 75).

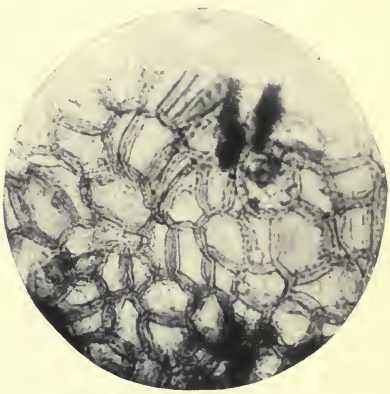


FIG. 3.—CANARIUM. SURFACE OF INTEGUMENT (× 175).

FIG. 4.—CANARIUM. STELLATE PARENCHYMA CELLS (× 175).

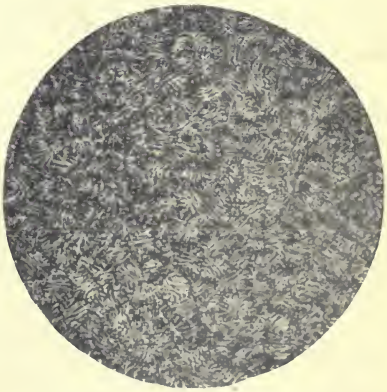
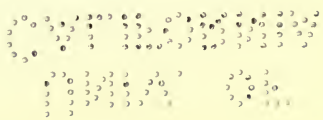


FIG. 5.—CANARIUM. ENDODERMIS OF SEED COAT (× 350).



consists of oil and aleurone grains. The latter are oval and quite regular in shape, with a crystalloid and one or two comparatively small globoid bodies. They occasionally reach a length of 12 to 15 μ, but those measured averaged only about 6 μ.

BRAZIL NUT.

(*Bertholletia nobilis* Miers,[1] Family *Lecythidaceæ*.)

The Brazil nut is the seed of a large South American tree which has been found too tender to thrive in any part of the United States. *B. excelsa* Humb. and Bonpl. produces a similar nut. The nuts owe their angular form to the fact that they are borne in dry pericarps or shells, each of which contains about 20 nuts packed closely together.

In addition to *B. nobilis* and *B. excelsa*, edible nuts are produced by a number of other trees of the same family, especially those of the genera Lecythis and Grias. *L. usitata* Miers yields the sapucaia nut, called also paradise nut, which has not yet become of great commercial importance, though it is of more delicate texture and finer quality than the Brazil nut and will doubtless meet with considerably greater demand in the market when better known.

The Brazil nut is one of the staple nuts on the American market and is too well known to require further description. The kernel, which comprises about 50 per cent of the nut, is firm, oily, and of good quality. The writer obtained 51.4, 52.8, and 52.9 per cent of kernels from three samples of Brazil nuts purchased in the Washington markets.

Histology.—Since the structure of the hard seed coat of the Brazil nut is described by Winton [2] further reference to it is omitted from this account. The inner brown tissue is composed of a number of layers of flattened cells, circular in outline and about 50 μ in diameter. The kernel, which frequently adheres to this tissue so closely as to be separated from it with difficulty, consists of the embryo surrounded by a layer of endosperm 40 to 50 μ thick, which is composed of a double layer of angular cells. The embryo itself is peculiar in that the radicle is very largely developed and is the place of storage of reserve food. The radicle is plainly differentiated into cortical and medullary tissues separated by a layer of procambium, along which rudimentary vascular bundles are arranged at intervals. The epidermal cells do not exceed 20 μ in diameter. The cortex consists of rather loosely arranged, approximately spherical cells varying from the size of the epidermal cells up to 80 μ in diameter. They are not arranged in layers, but the number of cells in a radial line, which amounted on the average in specimens examined to from 10

[1] Young, Pomona J. Econ. Bot., 1911, 1 (3): 122–127.
[2] Microscopy of Vegetable Foods, 1906, p. 312.

to 12, is doubtless subject to some variation. The procambium consists of a layer about three cells thick composed of thin-walled cells about 16 to 20 μ in cross section. They are elongated in the direction of the long axis of the embryo. The medullary tissue is composed of parenchyma cells rather more compactly arranged than in the cortex; they are also more angular in outline than the cortical cells, often radially elongated, and so arranged that the radial rows of cells, united end to end, may be traced for some distance through the tissue. Their diameter averages 50 to 60 μ, while individual cells occasionally reach a length of 100 μ. The vascular bundles, already mentioned, occur at rather wide intervals, and are very slightly developed. They usually contain two or three spiral vessels about 8 μ in diameter.

The arrangement of the various tissues is shown in the section in Plate III, fig. 2.

The cotyledons of the Brazil nut are very small and are located about 5 mm from the distal end of the kernel. They can sometimes be found with the aid of a lens after soaking the kernel in water. In a longitudinal section they appear closely appressed to the side of the kernel underneath the endosperm and measure about 750 by 175 μ. At the base of the cotyledons the cells of the cortex become reduced in size and for a short distance it is no longer differentiated from the medullary tissue, but continues above the base of the cotyledon as a thinner layer of tissue.

The reserve food stored in the kernels consists of oil globules and aleurone grains. The latter are irregular in shape, of large size, often 30 μ in length, and contain a large crystalloid and one or more globoid bodies.

The sapucaia nut (*Lecythis usitata* Miers) is very similar in structure to the Brazil nut. The cortex is somewhat thicker, equaling the diameter of about 14 cells. The endosperm consists of but a single layer of cells and the inner integument is very thin and contains rosette crystals.

PISTACHIO NUT OR GREEN ALMOND.

(*Pistacia vera* L., Family *Anacardiaceæ*.)

The pistachio nut is the seed of a tree native to the Mediterranean region and introduced sparingly into this country. It is, however, too tender for cultivation except in California and the southern States. The fruit, which is produced in clusters, is of the nature of a drupe with flesh that becomes dry at maturity, and a smooth stone or pit which separates easily into two valves. The seed roughly resembles in shape an elongated buckwheat grain; that is, it is approximately though irregularly triangular in cross section, blunt at one

end and rather pointed at the other. To the radicle, located at the more acute end of the grain, are attached the two large green cotyledons. These are so placed that one edge of each occupies an angle of the nut, which is, therefore, quite acute. The other edges of the cotyledons are flattened, and have a conspicuous depression near the distal end. The seed coat is thickest over the acute edges of the cotyledons and an adjacent semicircular area on each side of the nut. The endosperm is thickest near the border of this area and that surrounding the radicle. The thicker portions of the seed coat contain a dark red coloring matter, while the thinner portions are colorless, and show the green color of the cotyledons beneath.

Pistachio nuts are offered for sale in the larger cities, and are used to some extent in confections, etc. They have a peculiar, pleasant, and somewhat resinous flavor. It is said that other nuts are occasionally colored green in imitation of pistachio nuts.

Histology.—The epidermis of the seed coat consists of cells of variable shape, in some parts of the nut quite regular with few intercellular spaces, in others very irregular with many large or small spaces between the cells. They vary in extreme diameter from 15 to 160 μ (Pl. IV, fig. 1). In the transverse section (Pl. IV, fig. 2) an outer and an inner layer of periderm can be distinguished, although they are usually not sharply differentiated. The outer layer consists of a spongy tissue, the innermost cells of which are in some regions provided with thick walls, resulting in grotesquely-shaped sclerenchyma cells (Pl. IV, fig. 5). The inner layer, consisting of smaller and more regularly-shaped cells, contains the vascular bundles in the outer part.

The endodermis of the seed coat consists of polygonal cells, averaging about 8 μ in diameter, which have thick, beaded walls of characteristic appearance (Pl. IV, fig. 3). This layer is only about 5 μ thick; when viewed in cross section a few of the cells are seen to be divided by horizontal walls. It is not continuous, since it fades away into the parenchyma tissue of the thicker portion of the seed coat, where the latter becomes continuous with the perisperm.

The perisperm is the most restricted of all the tissues surrounding the embryo, as it underlies only the thickest area of the seed coat, is continuous with it, and spreads out under the endodermis as a thin sheet of collapsed-looking cells, which gradually thins out and disappears. In restricted areas it is somewhat thickened and contains needle-shaped bodies resembling crystals, but without polariscopic activity.

The endosperm likewise is not continuous and varies considerably in thickness. It constitutes a layer two or three cells in thickness under the thicker portions of the seed coat, becomes thicker toward the borders of this region, and then gradually disappears so that

it is lacking over the larger part of the surface of the nut. It is also thickened irregularly around the projecting radicle. The endosperm is easily distinguished from the cotyledons by its white color.

The embryo, as usual, is of simple structure. The surface of the cotyledons is covered by an epidermal layer of oblong and polygonal cells seldom over 15 μ long and usually at least half as broad (Pl. IV, fig. 4). This layer is not more than 10 μ thick, while the parenchyma cells of the cotyledons average about 40 μ in diameter. The aleurone grains are small and nearly circular in outline. They are most commonly 5 or 6 μ in diameter, with a few larger grains up to 15 μ in diameter.

CASHEW NUT.

(*Anacardium occidentale* L., Family *Anacardiaceæ*.)

The cashew tree has the peculiarity of producing both a fruit and an edible nut. The so-called fruit is in reality the enlarged fleshy, pear-shaped peduncle or fruit-stalk which bears at its distal end the fruit proper or nut, as it is more commonly called. (Fig. 10.) The latter is reniform, larger at the basal end, of a grayish or slate color, and has a hard, whitish mass of tissue in the sinus, representing the stigmatic surface of the carpel. The pericarp is of a stiff, leathery texture, consisting of dense epicarpal and endocarpal layers separated by a thick, spongy mesocarp, the cavities of which are filled with an acrid, poisonous oil. The composition and properties of this liquid have been investigated by various persons, whose results are summarized by Basiner.[1] It contains about 10 per cent of the active principle, cardol, the remainder being largely an inactive, fatty acid, named anacardic acid, besides which tannic acid and other substances are present in smaller amounts. As cardol is regarded as the active principle of poison ivy, *Rhus radicans*, it is not surprising that when applied to the skin symptoms resembling those of ivy poisoning should result, consisting of irritation, swelling, and an eczematose eruption as described by Basiner.[2] Taken internally, it is nearly or

FIG. 10.—Cashew nut.

[1] Die Vergiftung mit Ranunkelöl, Anemonin, und Cardol, Diss. Dorpat, 1881, pp. 38–46.
[2] Loc. cit., pp. 46–53.

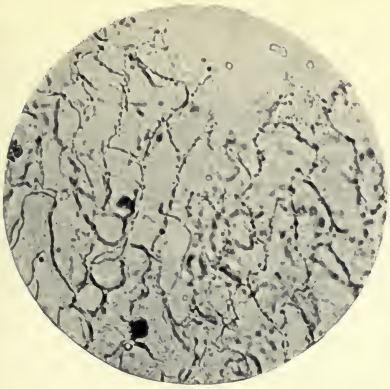


FIG. 1.—SURFACE OF INTEGUMENT (× 175).

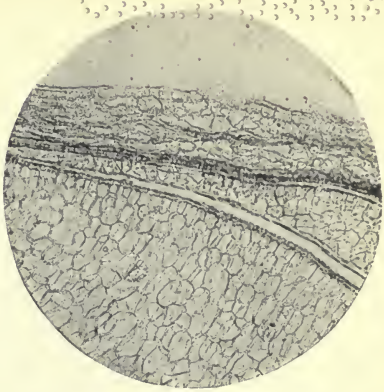


FIG. 2.—SECTION AT SURFACE OF KERNEL (× 75).

FIG. 3.—ENDODERMIS OF SEED COAT (× 350).

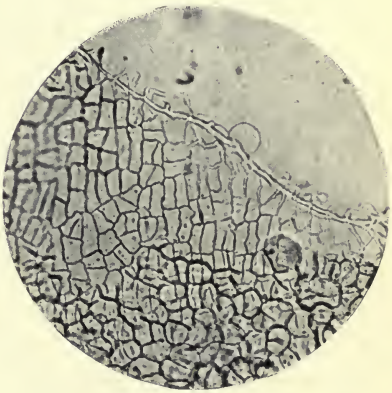


FIG. 4.—EPIDERMIS OF COTYLEDON (× 175).

FIG. 5.—SCLERENCHYMA CELLS FROM SEED COAT (× 175)

PISTACHIO NUT.

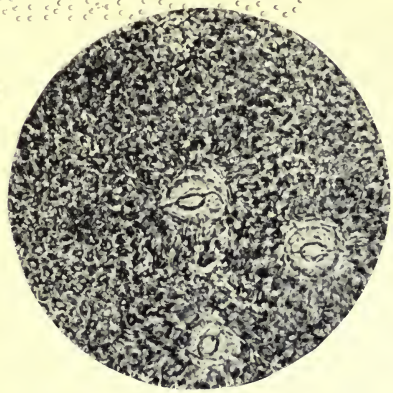


FIG. 1.—SURFACE VIEW OF EPICARP (× 175).

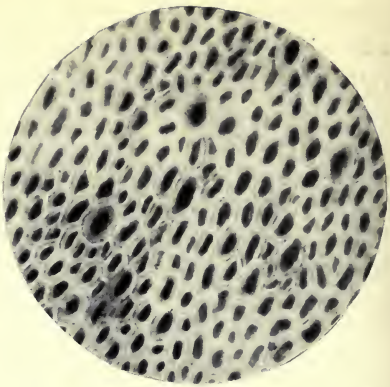


FIG. 2.—SURFACE VIEW OF ENDOCARP (× 175).

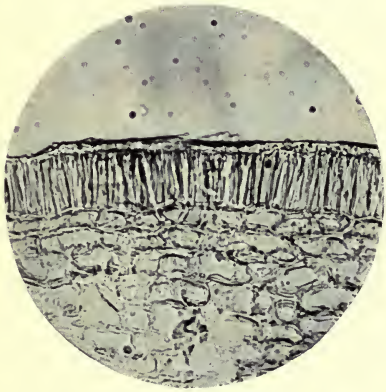


FIG. 3.—SECTION OF EPICARP (× 175).

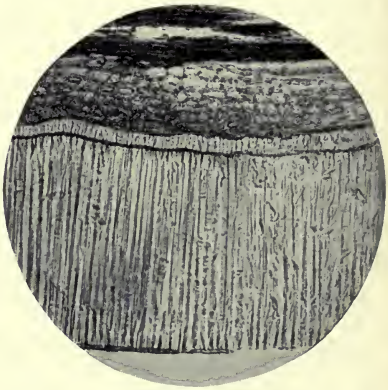


FIG. 4.—SECTION OF ENDOCARP (× 75).

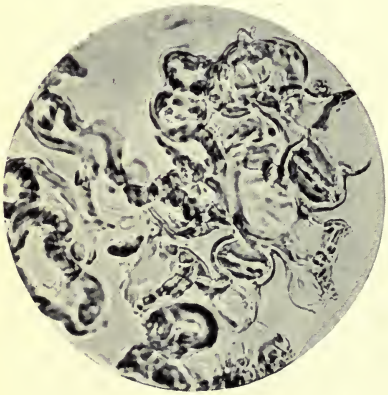


FIG. 5.—IRREGULARLY-SHAPED CELLS FROM SINUS OF NUT (× 350).

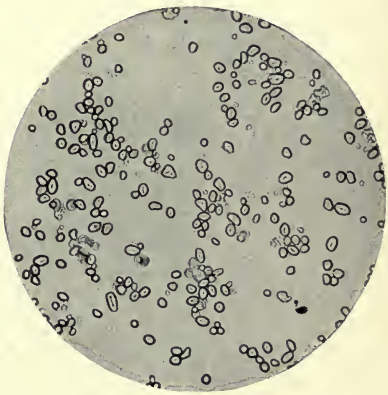


FIG. 6.—STARCH (× 400).

CASHEW NUT.

quite inactive. Buchheim [1] took three or four drops without noticing any effect, and Basiner [2] gave large doses to cats without producing fatal results.

It is customary to roast cashew nuts preparatory to eating. This process results in ridding the shells of cardol as well as in improving the flavor of the kernels. Cashew nuts so prepared are of the highest quality, but although imported to some extent for the use of confectioners they are not well known in this country. The writer has examined a sample of the unroasted nuts, which contained 30 per cent of kernels.

Histology.—Since no reference to the minute structure of the pericarp could be found in the literature, the subject was investigated in some detail. A cuticular layer 6 μ in thickness covers the surface of the epicarp, separating easily from the palisade layer underneath in such a way as to retain the outlines of the cells composing that layer. A careful examination, therefore, is necessary in order to demonstrate the absence of a cellular structure in the cuticle itself. The palisade tissue consists of columnar cells 40 to 50 μ in length and about 10 μ in diameter, which have moderately thick walls provided with longitudinal slitlike pores. (Pl. V, fig. 3.) Viewed from the outer surface (Pl. V, fig. 1), they are seen to be polygonal, and in some cases, especially upon focusing downward, the walls appear quite sinuous. The walls are thickest near the inner extremity of the cells. The palisade layer is penetrated at intervals by stomata 40 to 50 μ in length, which are sunken slightly below the general level of the surface. Underneath the guard cells columnar cells are lacking and a small respiratory chamber is noticed. Adjacent to the palisade tissue are 10 or more layers of thick-walled parenchyma cells, which in turn give place to the mesocarp tissues, larger cells, fibers, and vascular bundles, with which are associated the large oil-containing cavities already mentioned.

Toward the endocarp are found tissues similar to those beneath the epicarp. There are 6 to 10 layers of thick-walled, somewhat elongated parenchyma cells, similar to those which underlie the palisade layer of the epicarp and quite sharply marked off from the typical mesocarp tissue. At intervals those lying next the palisade tissue of the endocarp have their walls so much thickened as to form stone cells.

There are two layers of palisade cells, the first of which consists of cells only 20 to 25 μ in length, while in the second or inner layer the cells are 350 to 375 μ in length and 10 to 20 μ in diameter. (Pl. V, fig. 2.) The lumen is small and the walls thick, except at

[1] Ref. in Proc. Amer. Pharm. Assoc., 1874, 22: 156.
[2] Loc. cit., pp. 60–62.

the ends of the cells, where they become very much thinner. The endocarp is lined with a cuticular layer similar to that of the epicarp, which separates readily from the palisade layer and retains the outline of the cells. The arrangement of the tissues of the endocarp is shown in cross section. (Pl. V, fig. 4.)

The hard mass of tissue in the sinus of the nut consists of thick-walled, extremely irregular cells, united by swollen branches and provided with pores at the area of contact. (Pl. V, fig. 5.) Elsewhere the walls are smooth and apparently of even thickness.

The seed coat is of simple structure, consisting of several layers of parenchyma cells averaging about 40 μ in diameter. Numerous vascular bundles pass in wavy lines through this tissue. The outer layers of the seed coat comprise a soft, pithlike, pink or whitish tissue, thickest at the sinus, and composed of delicate, branching cells. The inner tissue is of a brownish color with polygonal cells and no intercellular spaces.

Viewed in the section, the outer portion of the seed coat appears as a colorless tissue composed of collapsed, thin-walled cells, which expand upon soaking so as to form a layer upward of half a millimeter in thickness. Vascular bundles occur in the inner part of this tissue, close to the brown layer which follows. The latter, composed of about half a dozen layers of cells, has a thickness of about 50 to 60 μ. Closely attached to the inner surface of the seed coat is an inconspicuous tissue about 10 μ thick, of collapsed appearance, apparently representing perisperm or more probably endosperm.

The embryo, which comprises the kernel, consists of the two fleshy cotyledons, bent to one side at the middle and joined at their bases to the conical protruding radicle. A section made at the surface of the kernel shows a remarkably even epidermal layer about 18 μ thick. In surface view these cells average about 12 to 15 μ in diameter and are often nearly rectangular. The vertical walls are beautifully beaded. The second layer consists of somewhat larger cells, less regularly arranged. Further inward the cells increase in size up to about 40 μ, and are nearly spherical, leaving very small intercellular spaces. They are filled with oil globules and oval starch grains mostly 5 to 12 μ in length, which strongly resemble a leguminous starch or that of the acorn. (Pl. V, fig. 6.)

CANARIUM NUT, OR JAVANESE ALMOND.

(*Canarium indicum* Stickm. Family *Burseraceæ*.)

The rich, oily kernels of the canarium nut are much relished by the natives of Oriental countries, but are not much known to Americans. The nut, which is imported to a limited extent, finds con-

sumers for the most part among the Orientals of the Pacific coast States. During the past season they have occasionally been found among mixed nuts.

The canarium tree is a native of the East Indies and Philippine Islands. The nuts are fusiform, somewhat triangular in cross section. The shell, which is thick and very hard, incloses a white, oily kernel enveloped by reddish-brown seed coats, which are comparatively thick and tough. The kernel consists of the cotyledons and other structures of the embryo. It separates readily from the seed coats; and if the inner surface of the latter be scraped lightly, a small amount of white tissue, which is largely endosperm, can be removed.

Histology.—Preparations of the seed coat viewed from the outer side reveal a superficial layer of cells averaging 50 μ in diameter, but occasionally reaching an extreme length of 100 μ. (Pl. III, fig. 3.) Their general shape is polygonal, with straight or slightly curved vertical walls of considerable thickness. The horizontal walls are sometimes traversed by slight thickenings, which can often be traced but a short distance from the vertical wall, thus forming a sort of false beading.

Underneath this epidermis is a thin layer of stellate parenchyma, composed of branched cells united with each other only at the ends of the branches, thus leaving large intercellular spaces. (Pl. III, fig. 4.) These cells are rich in tannin, as shown by the ferric chlorid reaction, and are similar in size to the cells of the overlying epidermal tissue. The inner layer of the seed coat consists of polygonal cells about 10 μ in diameter, with the walls strongly marked with tracheidlike thickenings. (Pl. III, fig. 5.) When viewed in section they are seen to be cup-shaped cells, with openings turned toward the parenchyma tissue of the integument.

Nearly all of the vascular tissue of the seed coat is included in one or two broad bands, running in general in a longitudinal direction. They are easily recognized, when the inner surface of the seed coat is examined, by their thickness and by their reddish color, which is much darker than that of the spermoderm itself. They are scarcely distinguishable on the outer surface. These vascular areas resemble in structure the other parts of the seed coat, except that the inner layer of cup-shaped cells gives way to a layer of nearly square, thin-walled cells about 15 μ in diameter. The greater thickness of this part of the seed coat is due largely to the vascular elements, mostly annular and scalariform vessels about 15 μ or less in diameter. The parenchyma tissue, which surrounds the vascular bundles, is quite fully developed. The cells are elongated in the direction of the vascular elements and branch almost entirely at the ends.

Upon examining sections of the seed coat a layer of clear tissue is found adhering closely to the inner surface. This is readily seen to be composed of two portions, an outer layer about 20 μ or less in thickness and not distinguishable into cells, probably representing the perisperm, and a much thicker inner layer, composed of two or three layers of cells representing the endosperm.

The embryo, which consists of parenchyma tissue lacking characteristic structure, is filled with oil globules and aleurone grains. The latter sometimes reach a length of 15 μ, but their usual size is not more than half as great.

KEY TO SPECIES OF NUTS.

The writer has prepared the following key to facilitate the microscopical identification of the species of nuts described in this paper. It is meant to be suggestive only, and persons making use of it should in all cases compare the material for identification, point by point, with the description of the species indicated by the key; or, better yet, with known material, if that can be obtained.

I. Epidermis of periderm containing stomata.
  A. Stomata normal; that is, ends of guard cells fitting squarely together.
    1. Outer tissue of integument consisting of one or two layers of cells, endosperm of one to three layers.
      a. Guard cells of stomata very broad, epidermal cells turgid and foamlike_____*Juglans regia*, p. 16.
      b. Guard cells narrower, sometimes one abortive; epidermal cells larger and more angular than in last___*Juglans cinerea*, p. 17.
      c. Stomata smaller than in *b*, nearly circular; guard cells rather narrow; sometimes approaching type *B;* epidermal cells angular and clouded in appearance_____*Juglans nigra*, p. 19.
      d. Guard cells very broad; epidermal cells angular and very small, usually about 20 μ in diameter_____*Juglans californica*, p. 22.
    2. Outer tissue of integument consisting of two to four layers of cells; endosperm one layer of cells.
      a. Stomata nearly circular; guard cells narrow, one sometimes abortive; length of epidermal cells averages about 75 μ, which is much greater than the width_____*Hicoria pecan*, p. 24.
      b. Stomata nearly circular but with thicker guard cells than the last; epidermal cells not so elongated____*Hicoria ovata*, p. 25.
  B. Stomata abnormal; that is, coiled nearly or quite into circles; outer tissue of integument consisting of a single cell layer.
    1. Guard cells narrow, much coiled so that opposite ends sometimes overlap; endosperm consisting of two or three cell layers.
      Juglans sieboldiana, p. 20.
    2. Guard cells broader, not so completely coiled; usually single layer of endosperm cells_____*Juglans californica hindsii*, p. 22.

II. Epidermis of periderm containing no stomata.
  A. Epidermis of periderm with papillæ usually developed into stone cells.
    1. Stone cells not developed or some cells with slightly thickened walls. Rosette crystals sometimes present.
      Amygdalus communis (soft-shelled), p. 9.

II. Epidermis of periderm containing no stomata—Continued.
A. Epidermis of periderm with stone cells—Continued.
2. Stone cells well developed.
a. Stone cells, single or in groups, usually forming noticeable papillæ; inner and lateral walls marked with variously-formed pores; rosette crystals often present.
α Stone cells forming distinct rounded papillæ, especially along the vascular bundles, their size not affected by location; endodermis indistinct; aleurone layer mostly single.
Amygdalus communis (hard-shelled), p. 10.
β Stone cells often forming flat-topped papillæ; groups of small stone cells along vascular bundles; endodermis comparatively distinct; aleurone tissue of four or more layers of cells——*Amygdalus persica*, p. 13.
b. Stone cells evenly distributed, their size not affected by location, dome-shaped; pores mostly circular; epidermal cells polygonal; rosette crystals absent.
α Stone cells mostly under 100 μ long; intercellular spaces small and slightly affecting form of stone cells; endosperm of single layer of cells——*Prunus armeniaca*, p. 12.
β Stone cells frequently over 100 μ long; intercellular spaces large, noticeably affecting shape of stone cells; thick masses of endosperm along the lateral faces of the kernel——*Prunus domestica*, p. 14.
B. Epidermis of periderm without stone cells.
1. Epidermis of periderm of angular, thick-walled cells.
a. Middle periderm layer of branched cells; endodermis of cup-shaped cells with tracheidlike thickenings in the walls.
Canarium indicum, p. 35.
2. Epidermis of periderm of variously-shaped cells usually with intercellular spaces.
a. Endodermis of very small polygonal cells with thick, beaded walls; endosperm and perisperm of variable thickness and incompletely distributed; cotyledons green.
Pistacia vera, p. 31.
3. Endodermis not characteristic; outer tissues of periderm resemble the epidermal cells in shape; endosperm of one or two cell layers continuous; cotyledons white——*Corylus avellana*, p. 27.
4. Epidermis of integument indefinite or absent.
a. Integument consisting of elongated cells several hundred microns in length; characteristic structures absent; aleurone grains very small——*Pinus* sp., p. 28.
b. Integument of roundish, flattened cells; embryo differentiated into cortical and medullary regions; aleurone grains large.
α Endosperm of about two cell layers; rosette crystals absent from integument——*Bertholletia nobilis*, p. 29.
β Endosperm of single cell layer; rosette crystals present in integument——*Lecythis usitata*, p. 30.
c. Integument of indefinite outer layer of delicate, colorless cells; inner layer of brown tissue. Endosperm inconspicuous; epidermis of cotyledons of angular cells with beaded walls; kernel contains starch——*Anacardium occidentale*, p. 33.

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